RESEARCH HIGHLIGHT

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Understanding Vapour Permeance and Condensation in Wall Assemblies

INTRODUCTION

Condensation inside walls is a performance problem in Canadian housing that can lead to rot, mold, corrosion, and/or staining. Condensation has typically been considered a cold weather concern. However, problems have also been documented in above-grade walls where moisture absorbed into porous non-ventilated claddings, such as wood, brick or stucco, is driven inward to condense on the exterior of low-permeance interior layers (that is, plastic vapour barriers or interior finishes) in air-conditioned buildings. Condensation problems have also been encountered with below-grade walls where inward drying of moisture, built into new concrete foundation walls or moving inward from the soil, is trapped by low-permeance vapour barriers (such as plastic sheets).

The use of low-permeance polyethylene sheets (6 mil polyethylene) as a combined air and vapour barrier is well integrated into building codes and the Canadian construction industry, as a result of significant investment in research and training. Their use as air barriers has resulted in an improvement in building envelope airtightness when properly detailed. Contractors and inspectors have developed a good understanding of the details and practices required to achieve airtightness in housing. However, because of the concerns that polyethylene vapour barriers may reduce or eliminate drying to the interior and exacerbate summer condensation, the vapour barrier function of the polyethylene has been questioned.

CMHC initiated a research program to investigate the significance or insignificance of potential moisture problems due to the use of low-permeance plastic sheeting in above-grade and below-grade wall assemblies. The research was intended to identify cases where performance could be improved, and provide information to help avoid inappropriate use.

BACKGROUND

Air has a limited capacity to hold water vapour: the maximum capacity decreases significantly as the temperature drops. Condensation occurs when the air's capacity at a surface is exceeded and water vapour changes to a liquid. Water vapour moves to a surface by two mechanisms: 1. vapour diffusion, the flow of vapour only from regions of high vapour content to regions of low vapour content, and 2. convection or air leakage, the flow of air from regions of high air pressure to regions of low pressure carrying water vapour along with it. Vapour barriers or vapour diffusion retarders address the flow of vapour by diffusion. Air barrier systems control the flow of vapour by air flow.

Air flow transports much more vapour than diffusion in most cases. Air barrier systems are always required, and can be provided in a number of different ways, for example:

- sealed, continuous and supported 6 mil polyethylene;
- sealed and continuous drywall;
- some sealed, continuous and supported housewrap products, etc.

Air barriers do more than control condensation, they also ensure thermal performance, reduce sound transmission and help ensure good indoor air quality.

In walls insulated with vapour-permeable insulation (such as fibreglass batt) and no vapour control, water vapour can diffuse to the exterior sheathing and condense. If the condensation is significant enough, and drying is insufficiently fast, the condensation can cause mold, decay, and/or corrosion. To control the amount of vapour transported by diffusion, vapour barriers (for example, 6 mil polyethylene, special paints, aluminum foil) can be used.

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HOME TO CANADIANS

In assemblies that are rarely warm or wet, the flow of vapour during drying will generally be towards the outside in Canada. This fact has resulted in the general rule that vapour barriers should be used on the interior of walls in Canada.

However, as vapour diffusion is also the major mechanism available for drying water trapped in a wall assembly, vapour barriers will also reduce the rate of drying. Walls that are exposed to the sun are likely to be warmer on the outside than the inside for some time of the year. Walls in warmer Canadian climates, such as Vancouver and Toronto, may experience vapour flow to the interior, especially in air-conditioned homes. Basements are always damp on the exterior side and often cool on the interior. In these cases, drying to the interior may occur if a vapour barrier is not present on the interior. In some cases, the flow of water vapour inward is so powerful that a low-permeance barrier like polyethylene on the inside can result in condensation on the exterior face of this barrier. This condensate can cause mold growth and decay of the framing.

The research project focused on the impacts of cold-weather condensation on exterior sheathing when no vapour barrier was used, and the impact of warm-weather condensation on the vapour barrier when polyethylene was used. In all cases, a functional air barrier system was provided, as this is required in all houses.

METHODOLOGY

The approach taken combined an extensive literature review and field testing of both above- and below-grade walls with parametric hygrothermal computer simulations.

Three types of full-scale walls (north and south duplicates; six walls total) were installed in the University of Waterloo's BEGHut exposure facility. Table 1 describes the wall assemblies chosen to compare poly to latex paint and the impact of insulating sheathing and orientation.

The interior of the hut was maintained at 50% relative humidity (RH) and 20° to 21°C year round. This is a high and dangerous interior relative humidity for winter conditions (it will result in extensive and persistent condensation on double-glazed windows), and was designed to cause significant outward wintertime diffusion wetting. The interior temperature is lower than most air-conditioned residential applications in summer (by 2° to 4°C), and this is expected to increase the duration and severity of inward flows and summer condensation problems. Drying of accidental moisture leaks was not considered.

Table 1 Above-grade wall assemblies

Layer	Above-grade wall 1: 2x6 with polyethylene	Above-grade wall 2: 2x6 without polyethylene	Above-grade wall 3: 2x4 with XPS, no polyethylene
Interior finish	½ in./12.7 mm gypsum wallboard w. latex paint	½ in./12.7 mm gypsum wallboard w. latex paint	½ in./12.7 mm gypsum wallboard w. latex paint
Vapour control layer	6 mil polyethylene	None	None
Framing/insulation	2x6 16 in. o.c. with R-20/RSI-3.5 fibreglass batt	2x6 16 in. o.c. with R-20/RSI-3.5 fibreglass batt	2x4 16 in. o.c. with R-12/RSI-2.1 fibreglass batt
Sheathing	½ in./12.7 mm OSB	½ in./12.7 mm OSB	1 in./25 mm XPS R-5/RSI 0.9
Water-resistive barrier	Spun-bonded polyolefin (SBPO) housewrap	Spun-bonded polyolefin (SBPO) housewrap	Spun-bonded polyolefin (SBPO) housewrap
Drainage cavity	1 in./25 mm space; bottom vents only	1 in./25 mm space; bottom vents only	1 in./25 mm space; bottom vents only
Cladding	Single wythe brick veneer	Single wythe brick veneer	Single wythe brick veneer

Four internally insulated basement wall insulation assemblies were constructed and monitored in a house in Kitchener, Ont. Installation and instrumentation were completed in the first year of service; the test walls are roughly south facing. The poured concrete basement wall assemblies are detailed in Table 2. The basement was newly constructed and no liquid water penetration problems were observed. The interior conditions in the basement were not tightly controlled, but the measurements indicated that interior moisture levels were about average (based on a previous CMHC survey of basement conditions).

All of the walls were instrumented with moisture content, condensation, temperature, and relative humidity sensors. Data was collected at five-minute intervals and the hourly average results stored for analysis. Full weather data were also collected.

The hygrothermal simulations extended the results of the field measurements. The *WUFI* Software program was first shown to be capable of predicting the measured above-grade wall results well and then used to consider a range of different interior humidity levels and exterior climates (St. John's, Edmonton and Vancouver).

RESULTS

Theory and previous research were summarized in the literature review. This confirmed that the need for vapour barriers depends on the interior humidity levels, the exterior temperature, and the makeup of the wall assembly.

The field monitoring of above-grade walls physically demonstrated and confirmed theory and experience: first, the presence of a polyethylene vapour barrier reduces the potential for wintertime diffusion condensation and moisture damage of the wall cavity at high interior relative humidity (50%) conditions. For example, in the no-poly north-facing walls, mold was found growing on the OSB sheathing. Second, the presence of the polyethylene increased the duration and intensity of summertime condensation in the stud bay cavity when using an absorptive cladding and relatively cool indoor conditions (20°-21°C). For example, the south-facing poly wall exhibited mold and staining on the interior of the framing lumber, particularly at the bottom.

Table 2 Internally-insulated basement wall assemblies

Layer	Below-grade wall 1: 2 in. XPS	Below-grade wall 2: vinyl fiberglass roll blanket	Below-grade wall 3: 2x4 with polyethylene	Below-grade wall 4: 2x4 without polyethylene
Interior finish	½ in./12.7 mm gypsum wallboard w. latex paint	Polyethylene roll blanket facing material	½ in./12.7 mm gypsum wallboard w. latex paint	½ in./12.7 mm gypsum wallboard w. latex paint
Other	19 mm / 3/4 in. airspace and furring strips	None	6 mil polyethylene	None
Framing/Insulation	2 in./50 mm extruded polystyrene (XPS) R-10/RSI 1.8	R-12/RSI-2.1 fibreglass roll blanket	2x4 16 in. o.c. with R-12/RSI-2.1 fibreglass	2x4 16 in.o.c. with R-12/RSI-2.1 fibreglass

Figure 1 Stain-free, south-facing no-polyethylene (left) and mold spots on north-facing, no-polyethylene wall

Please note:
The south-facing wall with extruded polystyrene foam sheathing had good performance; it showed the greatest resistance to summertime condensation from inward diffusion. However, the thermal resistance of the insulated sheathing was insufficient to avoid winter condensation and subsequent run down on the north-facing side under the test conditions: at least 1.5 in. (38 mm) would be needed for 50% interior RH in Toronto.

All of the south-facing walls benefited from solar heating in winter, which increased the weekly and monthly average temperature of the sheathing. This heating was sufficient to essentially eliminate the risk of cold weather condensation.

As noted above, the operating conditions of the test hut were chosen to challenge the walls: under more normal operating conditions, problems will be reduced or eliminated. However, colder conditions, such as in Edmonton or further north, will cause more condensation wetting in walls with latex paint unless the interior humidity is controlled to lower (and hence safer) levels.

None of the below-grade assemblies exhibited signs of major damage. The no-poly wall showed no signs of condensation or moisture staining. Both of the poly walls experienced summer condensation; it was particularly severe on the roll blanket wall (no. 2). The foam wall (no. 1) maintained the wood framing at stable and safe moisture contents, and will help avoid air leakage condensation. Note that the space between the concrete and foam must be carefully air-sealed to avoid connecting this high humidity zone with the interior air.

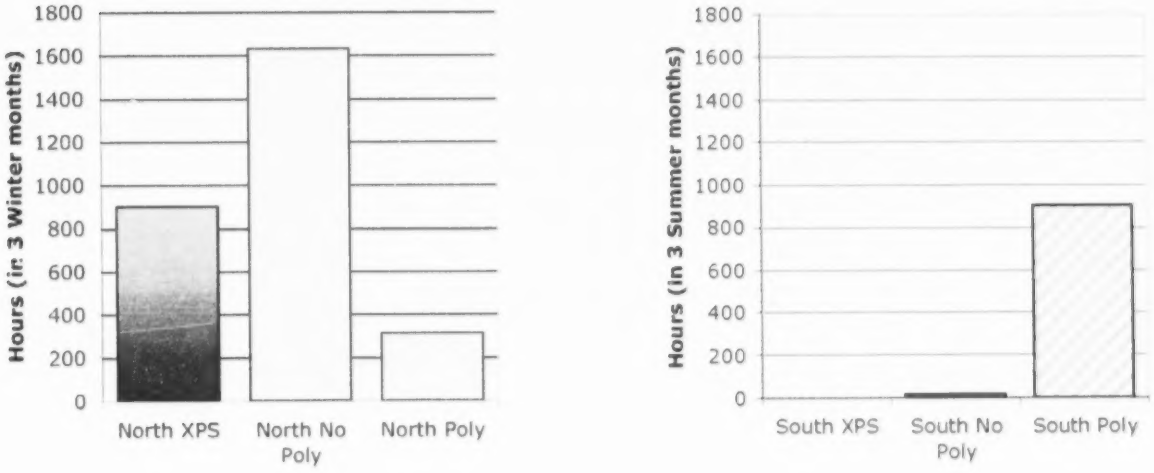

Figure 2 Hours of condensation risk measured in north (left) and south walls (right)

IMPLICATIONS FOR THE BUILDING INDUSTRY

Regardless of the vapour permeance of the materials used in a wall assembly, control of air flow through the enclosure must be provided by an effective air barrier system. Inadequate control of airflow remains by far the most significant source of condensation for both above- and below-grade assemblies.

Theory and previous research have confirmed that the need for vapour barriers depends on the interior humidity levels, the exterior temperature, and the makeup of the wall assembly. The field testing and simulation results from this study show that low permeance interior layers are required in some situations but not necessarily in others. Under conditions of high interior humidity and very cold exterior temperatures, mineral-fiber-insulated walls with no insulating sheathing will require low permeance (for example, under 60 metric perms) vapour barriers. In applications with lower (that is, safer) relative humidity levels, warmer Canadian climates and walls with exterior insulated sheathing, ordinary latex paint may be sufficient. The addition of insulating sheathing controls both cold weather and warm weather condensation without the use of plastic sheeting, but the R-value of the insulation must be sufficient to control winter-time condensation for the interior humidity expected. The report provides more detail on what combination of climate, interior relative humidity, and insulated sheathing controls cold weather condensation.

Under certain conditions weather condensation on plastic sheet vapour barriers can occur in air-conditioned buildings with rain-wetted absorbent cladding exposed to the sun. Condensation and warm temperatures can encourage mold growth.

This study considered 6 mil polyethylene sheets (3.5 metric perms) and latex paint (300 to 600 metric perms) vapour barriers: this is a range of permeance of more than a factor of 100. On-going work is investigating the role of vapour-control paints, which have permeance values of 30 to 120 metric perms. This research is expected to provide additional insight on vapour permeance and condensation in wall assemblies.

CMHC Project Manager: Don Fugler

Consultant: Halsall Associates Limited

Housing Research at CMHC

Under Part IX of the ***National Housing Act***, the Government of Canada provides funds to CMHC to conduct research into the social, economic and technical aspects of housing and related fields, and to undertake the publishing and distribution of the results of this research.

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or contact:

Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Phone: 1-800-668-2642
Fax: 1-800-245-9274

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